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ABSTRACT -- In 1975, a quaking aspen (*Populus tremuloides*) stand was clearcut. Fencing and slash retention treatments designed to exclude or impede livestock-use were implemented. We evaluated the effects of these treatments on regeneration of aspen 19 years later. Leaving all slash was as effective as fencing for maintaining aspen regeneration and supported adequate density of saplings to meet recommendations for ruffed grouse (*Bonasa umbellus*). Shrub cover also was greater in treatments with slash and fencing. Unfenced treatments with slash less than 8 cm diameter retained, did not differ statistically from fenced treatments, but did not support adequate aspen density to meet ruffed grouse habitat requirements. Data from our study are limited in scope and we expect the density of aspen saplings will vary in response to these treatments, elsewhere. However, we recommend retaining all slash after clearcutting aspen as an alternative to fencing for protecting the regenerating aspen suckers.

Key words: Aspen regeneration, grazing, long-term effects, Black Hills, South Dakota.

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Although quaking aspen (*Populus tremuloides*) communities comprise only about 5% of the Black Hills (Severson and Thilenius 1976), they are important for many species of wildlife (Buttery and Gillam 1983). Use of aspen by wildlife is affected by the density of aspen suckers and saplings. Bird species richness and diversity in the Black Hills are higher in dense aspen stands than open aspen stands (Mills 1994). Optimal ruffed grouse (*Bonasa umbellus*) habitats have 14,000-20,000 aspen saplings/ha (Gullion 1977).

When burned or clearcut, aspen clones vigorously regenerate through suckers (Fitzgerald and Bailey 1984, Jones and Schier 1985, Mueggler 1985). Because suppression of fires eliminates the natural disturbance for aspen regeneration (Jones and Debyle 1985), managers use clearcutting timber harvest to stimulate regeneration (Schier et al. 1985). If undisturbed, aspen suckers grow into dense even-aged sapling (less than 2.5 cm diameter at breast height) stands. Sapling aspen stands thin through natural competition into mature aspen or succeed to conifers (Krantz and Linder 1973, Bartos and Mueggler 1982, Jones and Schier 1985).

Early seral stages of aspen provide habitat for bird species preferring to nest in shrubs, whereas mature stands provide nesting habitat for both canopy- and ground-nesting birds (Debyle 1985a, Mills 1994). Understory shrub cover is important for nongame birds (Verner 1984) and ruffed grouse (Rusch and Keith 1971). Ruffed grouse use aspen stands of different size and density for breeding, nesting, brooding, and wintering (Gullion 1977, Debyle 1985a). Deer (*Odocoileus* spp.) and elk (*Cervus elaphus*) use aspen for both cover and forage (Collins and Urness 1983, Debyle 1985b, Kennedy 1992).

Abundant understory vegetation and succulent suckers attract cattle to the regenerating aspen (Reynolds 1969, Krantz and Linder 1973). Excessive cattle grazing reduces or eliminates regenerating aspen sprouts (Fitzgerald and Bailey 1984, Bailey et al. 1990, Christy and Vessels 1991). One defoliation of aspen suckers during August in the first year of growth may eliminate them (McCartney 1993). In the Black Hills, information on the long-term effects of cattle grazing on regenerating aspen is lacking.

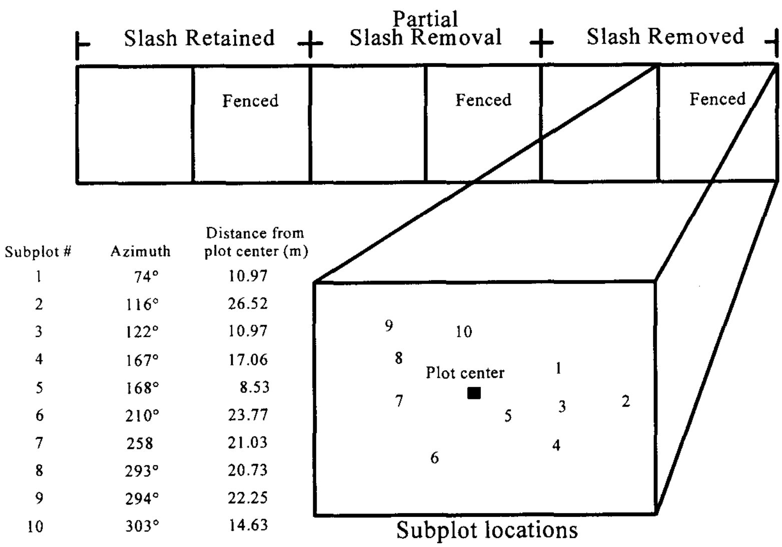
Our study evaluates the effects of management practices that limit or exclude livestock grazing on survival of aspen suckers 19 years following clearcutting of mature aspen. We compare the density of aspen saplings in six treatments: fenced and unfenced plots with (1) all woody debris from logging (slash) retained, (2) partial slash removed, (3) and all slash removed. We also document understory vegetation composition in these treatments.

STUDY SITE AND METHODS

Our study was conducted on the Nemo Ranger District, Black Hills National Forest. In 1975, a mature aspen stand was selected for our study. Trees averaged 60 years old, 1161 trees/ha, and averaged 14 cm diameter breast height (unpubl. data South Dakota Department of Game, Fish, and Parks, Rapid City). The stand also included paper birch (*Betula papyrifera*), bur oak (*Quercus macrocarpa*), white spruce (*Picea glauca*), and ponderosa pine (*Pinus ponderosa*).

We obtained grazing records of the allotment that included our study area (unpubl. data, Spearfish-Nemo Ranger District, Black Hills National Forest). From 1969 to present, this area was grazed by approximately 730 animal months in a season-long grazing system from 16 June to 15 October. Distribution of livestock within the allotment was identified as a problem. Meadows and riparian areas received heavy use by livestock and were in "poor" condition; secondary range including uplands and the remaining areas of the allotment were in fair to good condition. Our research plots were located adjacent to areas determined to be in "poor" condition.

Between June and November 1975, 2.43 ha of the stand were clearcut to stimulate aspen regeneration. This clearcut area was divided into three plots of 0.81 ha each, with the following slash treatments: all slash removed, firewood-size slash (less than 8 cm diameter) removed (partial slash retained), and all slash retained. Each 0.81-ha plot was further divided by a 3-strand barbed-wire fence so that half was fenced and half was unfenced (Fig. 1).



Subplot #	Azimuth	Distance from plot center (m)
1	74°	10.97
2	116°	26.52
3	122°	10.97
4	167°	17.06
5	168°	8.53
6	210°	23.77
7	258	21.03
8	293°	20.73
9	294°	22.25
10	303°	14.63

Figure 1. Experimental design of clearcut aspen to evaluate long term effects of fencing and slash treatments in the Black Hills, South Dakota.

Aspen stems were counted in ten, 4-m^2 subplots in each plot in 1976 and again in 1994. The azimuth and distance from the center of each plot to each of the subplots were drawn from a random numbers table, and were the same for all plots. We also characterized understory vegetation along four, 30-m transects established at 45°, 135°, 225°, and 315° from the center point in 1994. Percent cover of vegetation, litter, and logs (greater than 6.6 cm) in 30, 0.1-m^2 quadrats (Daubenmire 1959) was estimated at 1-m intervals along each transect.

Homogeneity of variance and normality assumptions for parametric statistics were evaluated for all data. We used analysis of covariance (aspen density in 1976 as the covariate) to test the hypothesis of no differences in density of aspen saplings among treatments. To evaluate the effects of slash treatments on aspen regeneration, we made two linear contrasts within the fenced treatments: (1) all slash removed with partial slash removed and (2) partial slash removed with all slash retained. To evaluate the effects of slash treatments on aspen regeneration with livestock grazing, we used linear contrasts in unfenced treatments to compare (1) all slash removed with partial slash removed and (2) partial slash retained with all slash retained. To evaluate the effectiveness of partial slash removal with livestock grazing on aspen regeneration, we made a linear contrast of unfenced partial slash removed with fenced treatments. Finally, to evaluate the effectiveness of retaining all slash in the presence of livestock grazing on aspen regeneration, we made a linear contrast of the unfenced treatment with all slash retained with all fenced treatments. Because we made more linear contrasts than permitted by the df, we used a Bonferroni correction to α for these contrasts to protect the experiment wise error rate. Percent cover for total vegetation, grasses, forbs, litter, logs, and major plant species was summarized for each transect and compared among treatments by using Welch's test (Milliken and Johnson 1984) and Tukey's T3 multiple comparison (Dunnett 1980). Statistical significance for all tests was determined at $\alpha = 0.05$.

RESULTS

Aspen Sapling Density

Slash did not affect the density of aspen saplings in fenced treatments ($P > 0.48$, Table 1). In unfenced treatments, aspen sapling density varied with the slash treatment; the highest density of aspen saplings occurred where all slash was retained and the lowest density occurred where all slash was removed ($P < 0.04$). When fenced treatments were contrasted with the unfenced treatment with all slash retained, no differences ($P = 0.66$) in the density of aspen saplings were apparent.

Table 1. Raw and adjusted mean ($\bar{x}$ ± SE) density of aspen saplings/ha 19 years after clearcutting with fencing and slash treatments[1].

Stems/ha X 1,000	Fenced			Unfenced		
	Slash Removed $\bar{x}$ ± SE	Partial Slash Retained $\bar{x}$ ± SE	All Slash Retained $\bar{x}$ ± SE	Slash Removed $\bar{x}$ ± SE	Partial Slash Retained $\bar{x}$ ± SE	All Slash Retained $\bar{x}$ ± SE
Raw	14.00 2.57	15.75 2.33	14.00 2.18	1.75 0.65	13.87 2.15	17.25 2.05
Adjusted[2]	14.38 1.90AB	14.70 1.93AB	16.58 2.03AB	1.75 1.90C	10.35 2.13B	18.78 1.95A

[1] Adjusted means followed by different letters in a row are significantly different $\alpha = 0.05$.
[2] Using analysis of covariance, means were adjusted based on the density of aspen suckers in 1976.

Table 2. Percent canopy cover of understory vegetation categories, and dominant shrubs and forbs beneath aspen stands 19 years after clearcutting, with fencing and slash treatments imposed.

Category	Fenced						Unfenced					
Species	All Slash Removed $\bar{x}$	± SE	Partial Slash Retained $\bar{x}$	± SE	All Slash Retained $\bar{x}$	± SE	All Slash Removed $\bar{x}$	± SE	Partial Slash Retained $\bar{x}$	± SE	All Slash Retained $\bar{x}$	± SE
Total cover	62.6	2.8B	65.6	2.4B	48.6	2.5A	78.6	1.0D	62.6	2.3B	52.8	2.7C
Total grass	12.3	2.3A	6.6	0.7A	8.4	3.4A	36.3	5.3B	20.2	7.6AB	10.3	3.9A
Total forbs	12.9	1.3AB	9.0	0.9AB	6.5	1.0A	13.3	1.2B	11.4	2.4B	6.8	1.2A
Achillea millefolium	0.8	0.4	0.5	0.1	<0.1	<0.1	2.1	0.9	1.1	0.6	0.2	0.1
Antennaria neglecta	0.1	0.1	0.4	0.1	0.2	0.1	0.4	0.1	0.1	0.1	0.2	0.2
Cirsium flodmanii	0.0		0.0		0.0		<0.1	<0.1	0.0		0.0	
Fragaria vesca	0.5	0.3	0.6	0.2	0.5	0.3	0.5	0.2	0.3	0.2	0.3	0.1
Galium boreale	1.4	0.7	0.5	0.1	1.5	0.4	0.6	0.3	0.7	0.3		
Lathyrus ochroleucus	0.3	0.2	0.6	0.3	0.7	0.2	<0.1	<0.1	0.7	0.2	0.2	0.1
Maianthemum canadense	0.0		0.0		0.7	0.5	0.0		0.8	0.3	0.2	0.1
Medicago lupulina	1.0	0.4	0.5	0.2	0.8	0.6	1.1	0.8	0.5	0.2	1.1	1.1
Monarda fistulosa	1.6	0.5AB	1.0	0.3AB	0.7	0.6AB	3.7	1.1B	2.9	1.4AB	0.3	0.1A
Taraxacum officinale	0.5	0.2	0.1	<0.1	0.2	0.1	<0.1	<0.1	0.2	0.1	0.5	0.2
Trifolium repens	1.9	0.8	0.9	0.5	0.1	0.1	1.5	0.7	2.1	0.7	0.1	<0.1
Viola adunca	1.0	0.4	1.1	0.2	<0.1	<0.1	0.0		<0.1	<0.1	0.3	0.2

Table 2. Continued...

Total shrubs	33.3	3.7B	36.6	3.5B	38.2	2.9B	17.1	2.9A	37.0	2.2B	39.5	4.9B
Amelanchier alnifolia	1.6	0.8A	1.2	0.7AB	1.1	0.5AB	0.2	0.1A	2.6	1.0B	5.1	1.7B
Arctostaphylos uva-ursi	0.8	0.3	<0.1	<0.1	1.6	1.5	0.0	0.0	1.4	0.8	0.7	0.6
Berberis repens	5.1	1.6	5.5	1.9	8.8	2.3	2.1	0.5	7.1	1.8	2.8	0.7
Corylus cornuta	0.8	0.6AB	0.6	0.5AB	2.2	0.2A	0.2	0.1B	0.5	0.5AB	9.4	3.8AB
Juniperus communis	<0.1	<0.1	0.0		0.1	<0.1	0.1	0.1	0.1	0.1	0.5	0.5
Prunus virginiana	0.6	0.5	<0.1	<0.1	1.3	0.7	0.0		0.6	0.6	0.3	0.1
Ribes spp.	0.3	0.1	<0.1	<0.1	0.4	0.4	0.0		0.1	0.1	0.6	0.2
Rosa woodsii	2.2	0.6B	0.6	0.1A	2.3	0.6B	0.2	0.1A	0.8	0.3AB	1.7	0.4AB
Shepherdia canadensis	0.5	0.3	0.5	0.3	0.1	0.1	0.5	0.5	1.6	0.9	0.0	
Spiraea lucida	3.6	1.2B	4.6	0.3B	3.3	1.0AB	0.4	0.2A	2.6	0.7AB	3.2	0.9AB
Symphoricarpos albus	11.0	1.7	7.2	0.7	9.5	1.6	8.8	0.9	12.3	1.6	9.6	2.7
Litter	96.1	0.8B	95.2	1.2B	95.6	0.9B	87.0	2.8A	92.5	1.7B	93.1	3.3AB
Bare ground	1.0	0.9	0.5	0.4	1.1	0.7	3.7	1.3	3.0	1.0	1.8	1.3
Logs	1.5	0.5AB	0.1	0.1A	12.5	2.1C	<0.1	<0.1A	0.6	0.5A	8.8	2.1BC

[1] Average percent canopy cover values followed by different letters in a row differ $\alpha = 0.05$, Welch's test.

Understory Vegetation

The unfenced treatment with slash removed had the most total understory vegetation, while the fenced treatment with all slash retained had the least (P = 0.03, Table 2). In the fenced treatments total understory cover was marginally lowest ($P < 0.07$) where slash was retained. In the unfenced treatments, total understory cover was also lowest ($P < 0.03$) where all slash was retained. Much of the increased vegetative cover in the unfenced treatment with slash removed was grass cover; it was only marginally greater ($P < 0.10$) than the fenced treatment with partial and all slash was removed. In the unfenced treatment, grass cover was similar between the all and partial slash removal; the former was only marginally greater ($P = 0.07$) than when all slash was retained. Canopy cover of forbs was greater in the unfenced with partial slash and both all slash removed treatments than treatments where all slash was retained.

Total shrub cover declined ($P < 0.05$) only in the unfenced treatment with all slash removed; all others did not differ. Percent cover of Saskatoon-serviceberry (*Amelanchier alnifolia*), beaked hazel (*Corylus cornuta*), and wild spiraea (*Spiraea lucida*) were lower ($P < 0.01$) in the unfenced treatment with all slash removed than the fenced treatment with all slash retained. The fenced treatment with all slash retained had only marginally more ($P < 0.08$) ground cover comprised of logs 19 years after treatments were applied.

DISCUSSION

Livestock grazing in the portions of the allotment that included our study indicated the area received excessive use of the range resource. During autumn when grasses and forbs are less palatable, cattle consume more trees and shrubs (Uresk and Paintner 1985) and aspen sprouts (Fitzgerald and Bailey 1984, Bailey et al. 1990). Season-long grazing of this allotment included late summer to fall grazing. Slash from logging creates an effective barrier to cattle and big game (Reynolds 1969, McAninch et al. 1983). Our study showed, that after 19 years, clearcut aspen that excluded livestock by either fencing or retention of all logging slash had higher densities of aspen saplings than clearcut aspen accessible to livestock.

Effects of grazing on aspen suckers were evident by 1976 in the unfenced plot with all slash removed. Clearcut aspen with fewer saplings had more herbaceous vegetative cover. High grass cover, most of which was Kentucky bluegrass (*Poa pratensis*) and reduced shrub cover in the unfenced plot with slash removed, resulted from grazing by livestock. During the first year, defoliation eliminated aspen suckers in Canada (McCartney 1993).

Our data suggest that in unfenced plots, partial retention of slash produced a slight increase in the density of aspen saplings over removal of all slash, but these effects were not statistically evident. Using the Bonferroni approach to maintaining experiment wise error rates, evaluation of the unfenced treatment with partial slash versus the fenced treatments also was not significant (P = 0.30). However, a more liberal statistical approach which used LSD comparisons showed a lower density of aspen saplings (P = 0.05) in the unfenced treatment with partial slash retained than in the fenced treatments. The LSD approach also suggested some intermediate responses of canopy cover of some understory plants to the unfenced treatment with partial slash when compared to the unfenced treatment with no slash and the fenced treatments. By 1984, the slash in partial slash retention treatments was mostly decomposed (A. Carter, pers. observ.). Thus, the unfenced plot with slash greater than 8 cm diameter removed (partial slash retained) no longer impeded livestock or deer; elk were not present before 1990 when 58 were reintroduced to this area.

High levels of slash following logging can reduce aspen suckers (Schier et al. 1985). In 1976, numbers of aspen suckers were lower ($P \leq 0.05$) in treatments where all slash was retained than treatments where slash was removed. By 1984, however, the effects of slash on aspen regeneration in these plots were no longer evident (Riley 1986). Nineteen years after clearcutting, densities of aspen saplings adjusted for initial suckers were 13% greater than where slash had been removed in fenced plots. Our fencing treatments did not exclude wild ungulates and this probably accounts for these effects.

Retaining all slash from logging or fencing resulted in more than 14,000 aspen saplings/ha. Retaining logging slash less than 8 cm diameter in unfenced plots, resulted in slightly greater density of aspen saplings. Several shrub species palatable to deer, elk, and livestock were more abundant in treatments that excluded livestock. Although our study has limited scope, we recommend retaining all logging slash as an alternative to fencing to ensure adequate densities of aspen saplings.

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